(1)

FEAP-UG-FE-94/15
June 1994

FACILITIES ENGINEERING APPLICATIONS PROGRAM

USER GUIDE

User Guide for Occupancy Sensor Lighting Controls in Army Administrative Facilities

by
Richard E. Rundus and Daiva Edgar
U.S. Army Construction Engineering Research Laboratories
Champaign, IL 61826-9005

Approved for Public Release; Distribution is Unlimited.

U.S. Army Engineering and Housing Support Center
Fort Belvoir, VA 22060-5516

PARTNERS IN PROGRESS

Innovative Ideas for the Operation, Maintenance, & Repair of Army Facilities

CONTENTS

TABLES

FIGURES

USER GUIDE FOR OCCUPANCY SENSOR LIGHTING CONTROLS IN ARMY ADMINISTRATIVE FACILITIES

1 EXECUTIVE SUMMARY

Occupancy sensors can reduce the amount of electrical energy used for lighting. They have received much attention in energy conservation articles, but vendor claims of savings vary widely. Several types are available. Application of sensors in various types of spaces, such as single offices, multiperson (group) offices, conference rooms, and restrooms, have different potential payback.

A field evaluation of occupancy sensors in Army administrative buildings was performed to define actual savings resulting from their use by quantifying energy savings and actual costs for installation. The evaluation took place at Fort Riley, KS, and included the installation of 30 sensors in two administrative facilities occupied by military personnel. Results of a 6-month test period, comparing energy consumption and lighting "on-time" (amount of time that lights are on) before and after occupancy sensor installation indicated energy use reductions of 30 percent in individual offices, 65 percent in restrooms, 60 percent in conference areas, 19 percent in classrooms, and 14 percent in group offices. Although the reduction in lighting on-time may be considerable, the economics must be evaluated carefully to determine if the retrofit is cost-effective. Such variables as electric utility rates, total controlled wattage (connected load) per sensor, space occupancy patterns, and total installed cost strongly influence the economic viability of a potential sensor retrofit opportunity. Installed costs for the ceiling-mounted sensors average $110 per sensor. Switch-mounted sensors, which were not part of the Fort Riley FEAP demonstration, typically cost $60, installed. At the Fort Riley demonstration, assuming an average reduction in lighting time for an individual office of 30 percent and an electrical cost of $0.06 per kilowatthour (kWh), annual savings were $45, yielding a simple payback for the sensor of 2.4 years.

Point of Contact:

Richard Rundus
U.S. Army Construction Engineering Research Laboratories (USACERL)
ATTN: CECER-FEM
P.O. Box 9005
Champaign, IL 61826-9005
217/373-3432 or 1-800-USA-CERL
FAX 217/373-7222

2 PRE-ACQUISITION

Description of the Technology

Occupancy sensors retrofitted to lighting systems provide a cost-effective means for reducing building electrical consumption by minimizing lighting on-time in various office and administrative spaces. Occupancy sensors ensure that lights in unoccupied spaces are automatically shut off shortly after the space is vacated. This technology can reduce the lighting contribution to building electrical consumption, and may extend the life of lamps and ballasts while not impacting the performance of the occupants.

The sensors typically use either ultrasonic or infrared (IR) technologies to determine whether a monitored space is occupied or not. Some newer sensors use both techniques, and are called hybrid technologies. However, hybrid sensors were not available at the time of this study, and are not included in the scope of this report. The technology used must be carefully chosen based on space size, type of activity, layout, and equipment in the space being considered.

Ultrasonic sensors generate inaudible, high-frequency (25-40 kHz) sound waves within the space, and use small microphones to detect changes or distortions in the reflected signal. These distortions result from motion within the space. Ultrasonic occupancy sensors can be effectively used to control lighting in very large rooms (up to 8500 sq ft) if properly selected, located, oriented, and tuned. This type of sensor is not appropriate in locations where moving equipment is present when the space is unoccupied. This moving equipment would include exposed, moving fan blades (from ceiling or floor fans), waving flags, moving mobiles, or activity in adjacent spaces that cannot be effectively blocked out by closing a door, installing partitions, reducing the sensitivity adjustment, or repositioning the sensor. The sensitivity of most ultrasonic units can be adjusted to minimize the false triggers, but this should be checked by testing the sensor within the space to ensure that it will work properly.

In addition to a sensitivity adjustment, most ultrasonic sensors have an adjustable time delay that can be set between 6 and 15 minutes by the installer. This time delay helps ensure that the lights are not shut off prematurely, while the space is still occupied or when the occupant has left for a short period of time. This time delay also prevents the lights from being cycled on and off too frequently. Lamp life is reduced as the number of on-off cycles increases.

Ultrasonic sensors can also be triggered by strong air motion and turbulence. Consequently, they should be located far enough from air diffusers, windows, and other sources of induced air flow to ensure proper operation. Most occupancy sensors come with product literature that details specific location guidance, including minimum distances allowed between the sensor and specific sources of ultrasonic disturbances.

Two ideal room types for ultrasonic technology are restrooms and open office environments with partitions. Partitions for workstations and toilet stalls create a barrier to IR sensors trying to detect occupants. Ultrasonic sensors have an advantage in these types of spaces, since they are able to detect occupant activity behind these barriers without requiring direct line-of-sight with personnel in the room.

Infrared occupancy sensors look for the range of temperature in the IR spectrum typically emitted by the human body (9 to 10 μm* wavelength). They sense changes in this infrared signal, which indicates that the space has been occupied. Unlike ultrasonic sensors, IR units require a direct line-of-sight view

---

*1 μm = 1×10^{-6}m

of the occupants to detect the presence (and movement) of people within the space being controlled. As with ultrasonic sensors, most units have an adjustable time delay (6 to 15 minutes, typically) between the last sensed human activity within the space and the sensor turning off the lights.

Infrared sensors are usually effective for spaces of 1000 sq ft or less for ceiling-mounted units, and 200 to 500 sq ft for wall-mounted units, depending on the product. Application restrictions for IR units are somewhat different than those for ultrasonic occupancy sensors. Since IR units detect changes or movements of specific temperature ranges within their field of view, they can be triggered by temperature changes that are not the result of people in the room. These false signals include air blowing through open windows, and heating and air-conditioning diffusers, or air-handler units. Sensor manufacturers specify minimum distances between air diffusers or windows and sensors to ensure that these false detections are avoided. Typically, IR sensors should be at least 4 ft from heating and air-conditioning diffusers. Additionally, some manufacturers recommend that the sensor be at least 1 ft from any fluorescent fixtures and ballasts, and at least two 2 ft from any incandescent light fixtures. The sensor should also be located so that its direct coverage area does not include any concentrated direct or reflected light sources.

Most IR sensors include masks that allow the installer to change the size and shape of the area that the sensor effectively covers. These masks can be installed if a particular source (such as a window or air diffuser) is creating false triggers. Proper location of the sensor and use of masks, where appropriate, can be critical to ensuring proper operation and greatest energy savings potential from passive IR occupancy sensors. The installation instructions provided with the sensors detail proper procedures for installing, tuning, and masking. These procedures vary between products, depending on design. The product-specific instructions should be followed carefully for adequate and efficient control of the lighting system.

Life Cycle Costs and Benefits

Single-technology occupancy sensors purchased for the FEAP project typically ranged in price from $40 to $80 for ceiling-mounted technologies, depending on the type of sensor and type of lighting system being controlled. This price included the control relay. Wall-mounted sensors, which replace manual switches, average $50 per sensor on the current General Services Administration (GSA) Schedule. Several of the wall-mounted sensors can be purchased for less than $40. Table 1 provides average prices for retail purchase of the sensors in quantities of 100. Prices are an average of all vendors that offer the specific technology and mounting location indicated in the table. The range of prices for any specific sensor application is fairly wide—suggesting that care should be taken to shop for sensor technology that meets specific application needs and is least expensive. Most of the ceiling-mounted sensor prices do not include the control relay. The wall-mounted sensor prices typically include an internal control relay. The control relays range in price from $18 to $80, depending on maximum connected load, and allowable number of sensors to control the relay. Table 1 also details the median prices and ranges for the various sensor technologies, along with the power packs or control relays. These median prices may be more useful for determining the probable cost of purchasing a specific sensor technology. The average price is higher than the median prices due to the relative few sensors in each category that are sold at the high end of the price range. Individual vendors' prices should be confirmed before calculating the specific economics of potential sensor installation projects. Prices for sensors that have national stock numbers were not available, but may be significantly less than the prices quoted by manufacturers. The local installation supply officer can provide current prices for sensors with national stock numbers.

Table 1

Occupancy Sensor Prices (non-GSA)

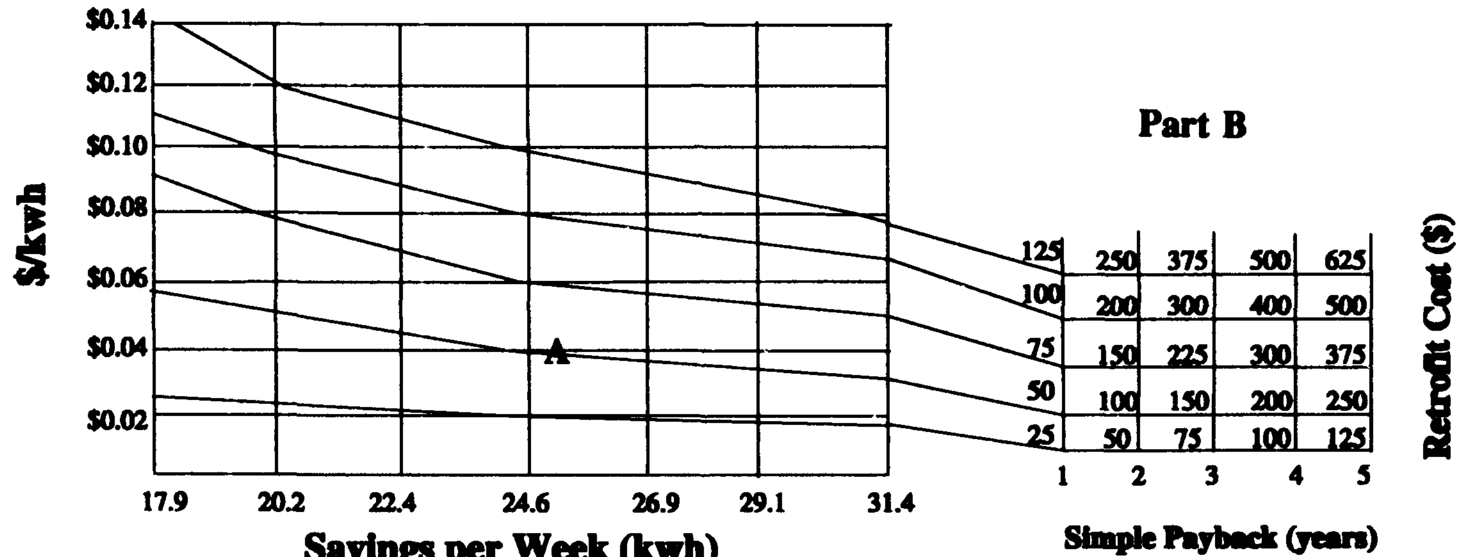
Technology	Price Range	Median Price	Average Price
Wall Infrared	$33 - $88	$56	$56.00
Ceiling Infrared	$43 - $120	$75	$77.36
Other Infrared	$40 - $147	$74	$76.90
Wall Ultrasonic	$53 - $80	$60	$65.78
Ceiling Ultrasonic	$60 - $138	$88	$94.80
Other Ultrasonic	$70 - $120	$100	$97.73
Power Packs	$18 - 80	$25	$36.00

The average installed cost was $110 for ceiling-mounted units at Fort Riley. This cost included the sensor hardware and 1 hour of electrician's labor for installation and tuning. No wall-mounted sensors were installed at Fort Riley, but current market information and projects using this technology indicate installed costs average $60 for material and labor. The actual energy savings will vary depending on the type of space, the typical occupancy rate during the occupied hours, and the total lighting load being controlled by the occupancy sensor.

Figures 1 through 4 estimate the simple payback for occupancy sensors in the four space types evaluated for the FEAP project. These figures allow the user to select the utility cost and the retrofit cost. The connected lighting load (kilowatt [kW]/sensor) is based on the FEAP demonstration performed at Fort Riley. These connected loads may vary in other facilities, and these figures cannot be used to determine the simple payback of dissimilar spaces. Table 2 shows the assumed wattage per sensor. These values are based on the average connected load for the sensors installed in the administrative buildings at Fort Riley. If the connected lighting load is not within the range provided, then Equations 1 through 3 can be used to determine simple payback.

To use the figures, choose the space type to be evaluated and select the appropriate savings per week from Part A, based on the hours per week that the sensor will turn off the lights (hours in effect). In Figure 1, Restrooms, the lights are assumed on 24 hours per day, 7 days a week. The hours in effect are based on this value. For the other figures, the assumed light operation is 45 hours per week prior to sensor retrofit. The values in Part C reflect the potential reduction in light operation per week as a result of the sensor installation. Once the savings per week are known, that value can be located on Part A and the intersection of this value and the utility rate ($/kWh) can be located. By following the curved lines from Part A to Part B and locating the retrofit cost, the simple payback can be read from the bottom of Part B. Conversely, if the installed cost and utility rate are known and a minimum desired payback is selected, then the savings per week to achieve this payback can be determined from Part A. Using Part C, the minimum hours per week that the sensor must turn the lights off can be determined. Spaces with the same connected load and similar usage patterns can be checked to determine if they will qualify for retrofit consideration.

Restroom

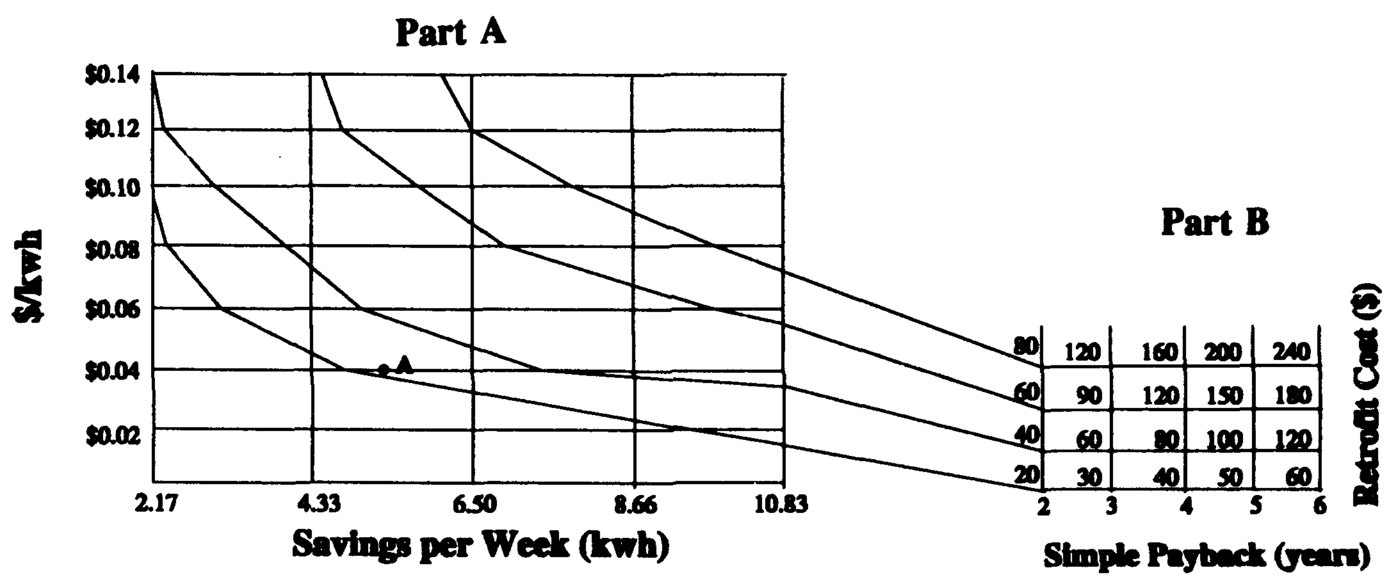


kwh saved	17.9	20.2	22.4	24.6	26.9	29.1	31.4
hrs in effect	80	90	100	110	120	130	140

Part C

Figure 1. Weekly and Yearly Payback for Restrooms.

Individual Office



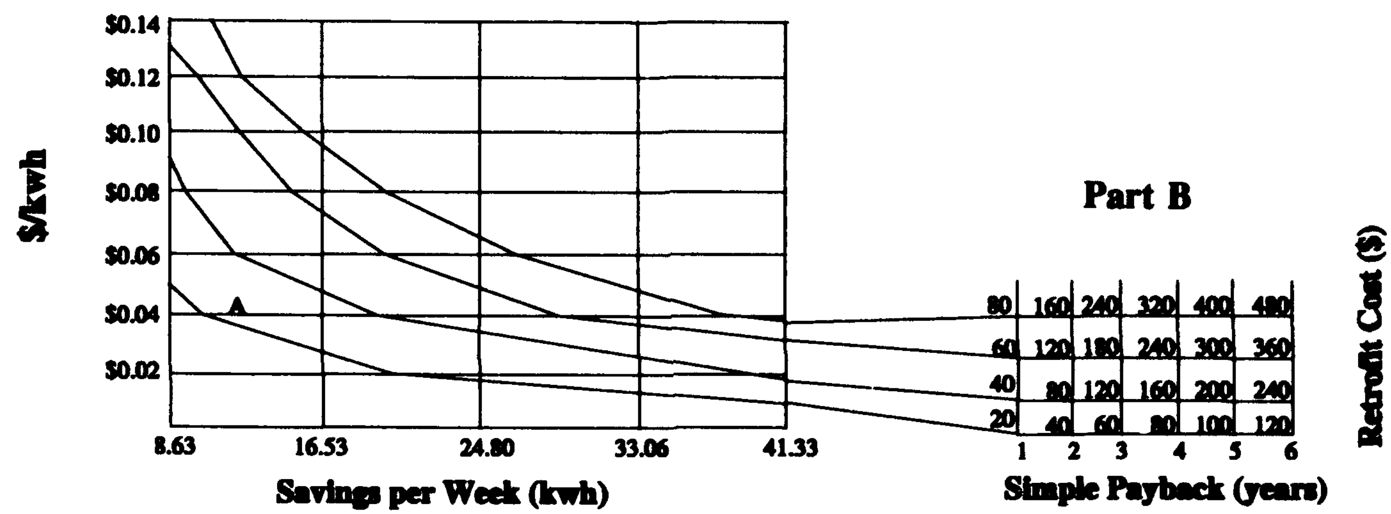
kwh saved	2.17	4.33	6.50	8.66	10.83
hours in effect	5	10	15	20	25

Part C

Figure 2. Weekly and Yearly Payback for Individual Offices.

Group Office

Part A

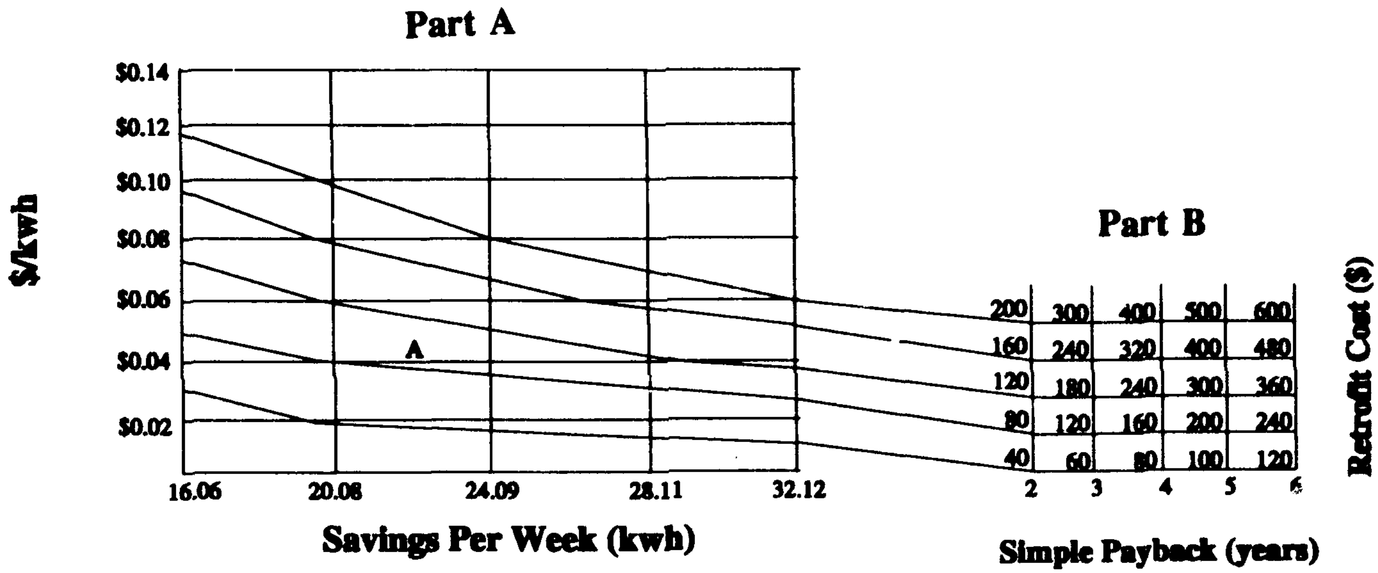


kwh saved	8.63	16.53	24.80	33.06	41.33
hours in effect	5	10	15	20	25

Part C

Figure 3. Weekly and Yearly Payback for Group Offices.

Conference Room



kwh saved	16.06	20.08	24.09	28.11	32.12
hours in effect	20	25	30	35	40

Part C

Figure 4. Weekly and Yearly Payback for Conference Rooms.

The life-cycle cost (LCC) savings for each space type evaluated at Fort Riley were calculated using the Life-Cycle Cost in Design (LCCID) software program, developed by USACERL. Table 3 contains a summary of this analysis. The LCC before retrofit reflects the discounted value of energy consumed over the 15 years of the project. The LCC after retrofit column indicates the reduced present net worth of the occupancy sensor retrofit including an installed cost of $110 per sensor the first year, and the reduced energy consumption resulting from sensor operation over a 15-year life expectancy. The cost of electricity of $0.039/kWh was used, and recurring maintenance and repair (M&R) costs were assumed to be negligible. A complete printout of the LCCID analysis for the FEAP program at Fort Riley is contained in Appendix A.

The largest reductions in lighting on-time occurred in conference spaces, classrooms, and restrooms at Fort Riley. Care must be taken when using these results, however, to ensure that the space has a sufficiently high connected load per sensor to make the retrofit life cycle cost-effective.

Personal observation and occupant feedback of the spaces being considered for an occupancy sensor retrofit are typically the best indicators of potential for lighting control retrofit. Periodic building walk-throughs can point out rooms where the lights are left on when nobody is in them. Once these spaces are identified, some simple calculations can help quantify the energy savings potential and simple payback for a sensor retrofit.

Table 2

Average Connected Load per Sensor at Fort Riley FEAP

Type of Room	Load per sensor (kW)
Individual office	0.433
Group office	1.653
Conference room	0.803
Restroom	0.224

Table 3

Life-Cycle Costs and Simple Payback for Fort Riley Occupancy Sensor Retrofit

Type of Area	LCC before retrofit	LCC after retrofit	Estimated Simple Payback (years)
Conference room	$790	$426	2.50
Restroom	$823	$398	2.22
Group office	$1626	$1509	5.20
Individual office	$426	$408	9.25
Wall switch in individual office	$426	$358	5.05

The energy savings potential of an occupancy sensor retrofit is a function of the connected load in the candidate space, the cost of electricity, the typical number of hours of operation per day (or year), and the anticipated reduction in lighting on-time as a result of the retrofit. The following equation should be used to determine this savings.

$$\text{DAILY SAVINGS} = (L) \times (R/100) \times (t) \times (Ce) \qquad \text{[Eq 1]}$$

Variables:

L = Lighting load connected to sensor [kW]
R = Reduction in light on-time per day with sensor [%]
t = Lighting on-time per day without sensor [hrs/day]
Ce = Electrical energy cost [$/kWh]

Assumptions:

- 260 workdays per year, except for restrooms which are typically on 24 hours a day, 7 days a week
- Installed cost of $110 per occupancy sensor (ceiling mounted sensors).

Simple payback for the occupancy sensor can then be calculated by simply dividing the predicted annual savings for the sensor by its total cost, including installation.

Example Calculation:

Assume an individual office where the typical reduction in lighting on-time is 30 percent:

L = 0.5 kW (500 Watts lighting load)
R = 30%
t = 10 hours/day
Ce = $0.039/kWh

$$\begin{aligned}\text{SAVINGS} &= (L)(R/100)(t)(Ce)\\ &= (0.5\ \text{kW})(.30)(10\text{hrs/day})(\$0.039/\text{kWh})\\ &= \$0.0585/\text{day}\end{aligned}$$

Multiply this by the number of workdays per year to determine annual savings:

$$\begin{aligned}\text{ANNUAL SAVINGS} &= (\text{DAILY SAVINGS})(\text{DAYS/YEAR OF OPERATION}) \qquad \text{[Eq 2]}\\ &= (\$0.0585/\text{day})(260\text{days/year})\\ &= \$15.21\end{aligned}$$

Then determine simple payback:

$$\begin{aligned}\text{SIMPLE PAYBACK} &= \text{SENSOR COST/ANNUAL SAVINGS} \qquad \text{[Eq 3]}\\ &= \$110/(\$15.21/\text{year})\\ &= 7.23\ \text{YEARS}\end{aligned}$$

The annual savings, simple payback, and life-cycle savings calculations can be further refined by performing an economic analysis using an automated economic analysis tool such as LCCID, which includes inflation rates, energy escalation rates, and other savings factors.

Typically, occupancy sensor implementations can be very cost-effective lighting energy conservation retrofits. Spaces to be retrofitted should be selected carefully and the type of occupancy sensor should be matched to space characteristics. Proper location of the sensor within the space, and proper tuning and adjustment of the sensitivity and time delay, can provide an effective means of ensuring that lights remain on only when the space is occupied.

3 ACQUISITION/PROCUREMENT

Potential Funding Sources

Possible sources of funding for occupancy sensor lighting controls include the Energy Conservation Investment Program (ECIP), Major Army Command (MACOM) Energy Funding, and the Directorate of Engineering and Housing, Operation and Maintenance, Army (DEH OMA). Guidance on ECIP funding is available from the U.S. Army Center for Public Works (USACPW), Fort Belvoir, VA. Their memorandum dated 4 November 1992 ("Energy Conservation Investment Program [ECIP] Guidance"), provides the most recent implementation guidance for ECIP projects.

Technology Components and Sources

For typical sensor applications, all of the required components are supplied by the vendor of the selected product. In some spaces where the proper location of a ceiling-mounted sensor is difficult to determine from space configuration and furniture layout, it may be beneficial to place the sensor on a test pole. The test pole can easily be moved around the room to determine the optimum sensor location before hard-wiring it to the lighting circuits. Figure 5 shows a typical test pole that can be fabricated from a microphone stand and an expendable pole, with a temporary mount attached. This mount would allow the sensor to be placed near its intended permanent location in the ceiling and to maintain the "field of view" that would be expected when permanently mounted at this location in the room. It is important that the design of this mount minimizes the blockage of IR sensor lenses or ultrasonic sensor emitters and microphones. Additional hardware for this work would include an extension cord to power the sensor and relay pack and a step ladder to allow adjustment of the sensor while at its intended mounting location. A portable light that can be powered by the sensor may be required for sensors that do not have a light emitting diode (LED) to indicate motion detection, or for rooms that are so large that the LED cannot be seen by the person doing the location testing when they are at the limits of the sensor's detection range. The light would be switched on and off by the sensor when motion is detected.

Additional hardware that may be required for sensor installation includes off-the-shelf electrical supplies such as wire nuts, or other approved wire-connection hardware for the high and low voltage* connection of the sensor to the lighting circuits. If a sensor bypass switch is required, then conduit connectors, a single pole, single throw (SPST) switch, and associated installation hardware and tools will be needed. These items are standard equipment in any electrician's inventory.

The work required to select the appropriate spaces, site the sensor location, and install the sensors can be easily performed by in-house staff. Once the spaces have been selected, and sensors located, the installation work can be performed by any certified electrician. Tuning of the sensor's sensitivity can be readily performed by following the product instructions, using either in-house staff or contracted support.

---

*high voltage: 120, 208, 277 volts
low voltage: 24 volts

Procurement Documents

1. Performance plans and installation specifications, including hardware and wiring modifications, are subject to applicable sections of the National Electric Code and Corps of Engineers Guide Specification (CEGS) 16415, *Electrical Work, Interior*. No existing Guide Specification specifically addresses the requirements for occupancy sensor circuit design, performance, or installation. Typical wiring diagrams for occupancy sensor installation or retrofit have been included in this user guide for general guidance. The manufacturer or vendor of the selected sensor technology can provide product-specific wiring diagrams and installation details.

2. Appendix B of this guide includes a list of manufacturers and marketers of occupancy sensor lighting control products. This listing identifies whether the retailer has the products on GSA Schedule and whether the product is made in the United States. Since there are a number of vendor [illegible] provided sensor technologies on GSA Schedule that are made in this country, there is no need [illegible] a Buy American waiver or to sole source the sensors.

Procurement Scheduling

Occupancy sensors are off-the-shelf items stocked at regional distribution centers. These products can generally be purchased without delay, allowing a minimal lead time for order processing, handling, and delivery.

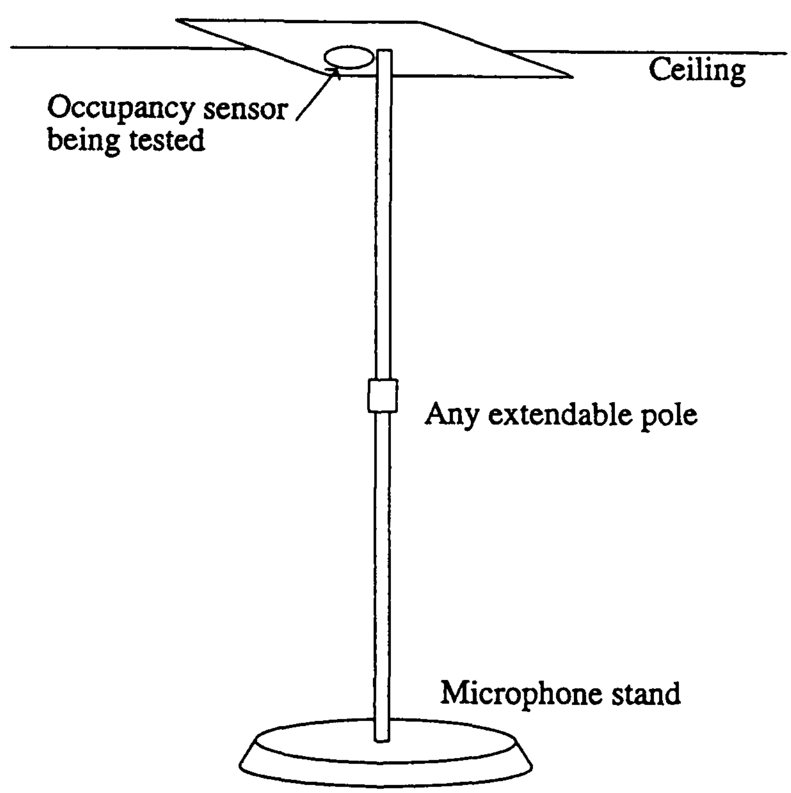


Figure 5. Test Pole.

4 POST-ACQUISITION

Initial Implementation

Once the retrofit spaces have been identified and the sensors have been purchased, three basic steps are required to complete the occupancy sensor implementation:

Step 1. Locating the sensor within the space. A site visit must be done to determine the proper location for the ceiling-mounted sensors. For wall-mounted sensors, this step is not required, since the sensor location is determined by the existing switch placement. This task should require one person no more than 15 minutes per space type. In many rooms the location is readily apparent, and a quick check of this location to ensure that the sensor has adequate coverage and orientation is all that is required. Where many similar types and layouts of rooms exist, this siting needs to be performed for only one typical space.

Step 2. Installing the sensor. An electrician must install the sensor. Then, an initial tuning of the time delay and sensitivity can be done by the electrician or any DEH staff familiar with sensor tuning. Wall-mounted sensors require approximately 10 minutes to install and require no special tools. The average time for installing and wiring ceiling-mounted sensors was 1 hour for the Fort Riley demonstration. This allowed adequate time to cut holes in the ceiling or to remove ceiling tile for access to the wiring, installation of the sensor and relay, as well as preliminary adjustment. Many of the spaces will require much less installation time per sensor. During installation, the power should be disconnected to the lights and other safety precautions taken to ensure a safe installation. Coordination with room occupants will be required to minimize the impact on their productivity. Figures 6 through 9 depict typical circuit designs with occupancy sensor for both ceiling-mounted and wall-mounted units, including sensor wiring circuits for three-way switching lighting circuits.

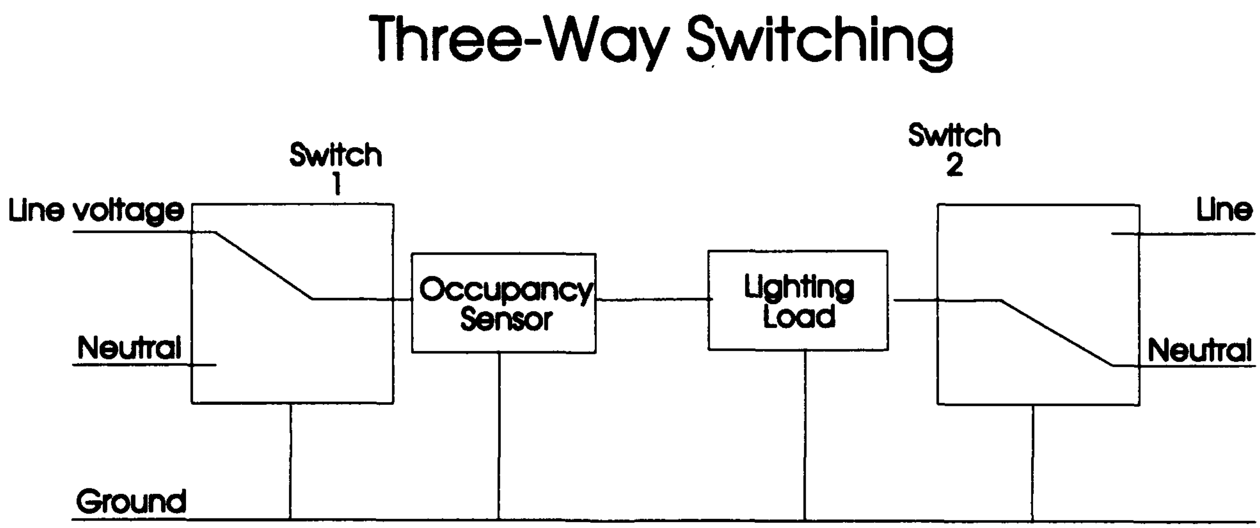


Figure 6. Three-Way Switch With Occupancy Sensor.

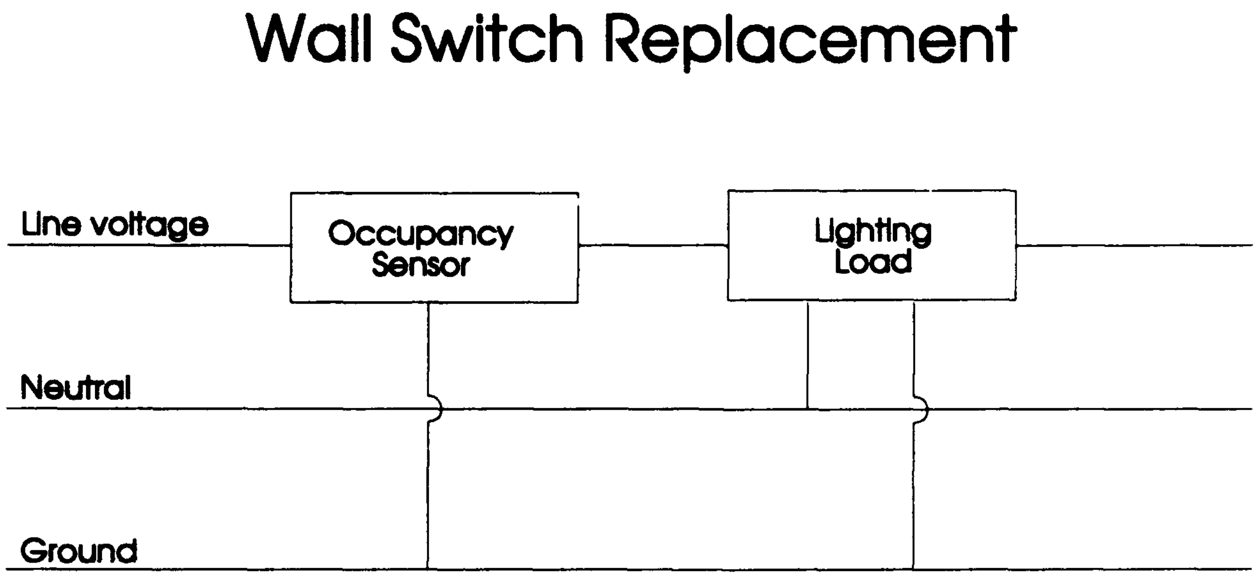


Figure 7. Wall-Mounted Sensor Wiring.

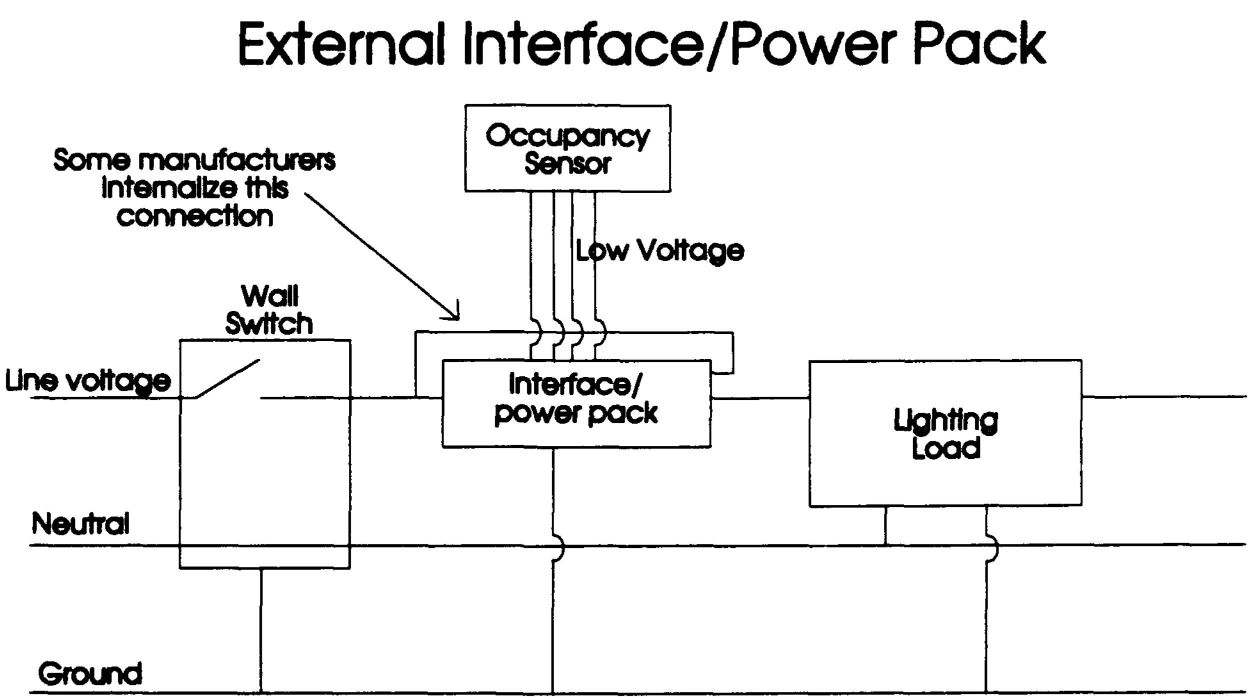


Figure 8. Sensor Wiring With External Power Pack.

Internal Interface/Power Pack

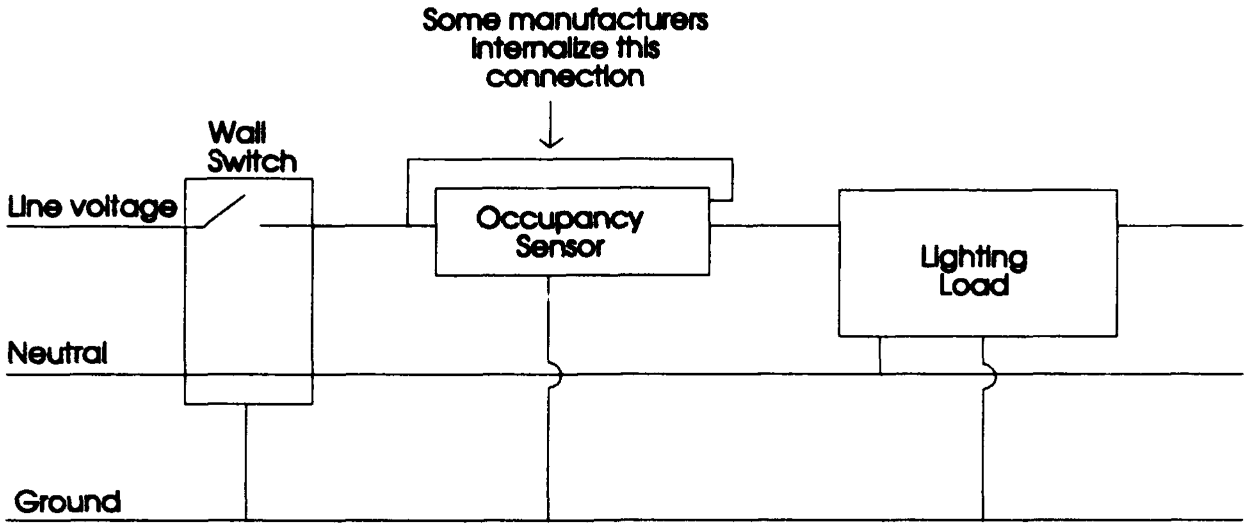


Figure 9. Sensor Wiring With Internal Power Pack.

Step 3. Tuning the controls for optimum performance. The sensor must be tuned to ensure that the sensitivity and time delay are adjusted to keep the lights on when occupied. Many sensors have a test mode that allows the lights to cycle off quickly, and allows the installer to efficiently check the sensor by walking through all regions of the space. Many of the sensors also have an LED that provides visual verification that the sensor is detecting movement. Care must be taken in tuning the sensor so it does not turn on the lights when there is motion in an adjacent space (such as a hallway). Some IR sensors come with masking kits that allow fields of vision to be covered, to eliminate false detections. To minimize false triggers with ultrasonic units, either the sensors must be reoriented or the sensitivity must be reduced.

Operations and Maintenance of Technology

Occupancy sensors require no periodic maintenance after proper installation and operation has been verified. If an IR sensor is located in a space that is very dirty or dusty, the sensor lenses may need to cleaned periodically for proper operation. No special skills are required for this operation.

If the usage or furniture layout of a space is altered, the sensor should be checked to verify that it still provides effective control of the lights. If the new space configuration or usage does not allow adequate coverage of the space, or ensure that lights remain on when the space is occupied, then the sensitivity should be increased. If the sensitivity adjustment does not provide satisfactory operation, the sensor may have to be relocated, or additional sensors installed. Most sensor technologies will support multiple sensors connected to a single relay to control a lighting circuit.

Service and Support Requirements

Occupancy sensors require no special service or support requirements. Routine maintenance and adjustments can be handled by DEH staff. Tuning and troubleshooting procedures are typically provided by vendors as part of the installation and operation instructions.

Performance Monitoring

The cost of data acquisition and monitoring circuitry to measure the actual energy savings or changes in lighting on-time would be prohibitively expensive for occupancy sensor installations. A much simpler approach to performance monitoring may be used. The DEH should perform an initial system operation check to see if the location, sensitivity settings, and delay times are working properly. After several days of operation, a followup visit should be scheduled to discuss the adequacy of settings with the room occupants. If there are no complaints, no further monitoring or tuning is required unless the space usage or furniture layout is significantly modified.

METRIC CONVERSION FACTORS

1 ft = 0.305 m
1 sq ft = 0.093 m^2

APPENDIX A: LCCID Summary Report for Fort Riley Occupancy Sensor Lighting Control Demonstration

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: TOTAL
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.065
INSTALLATION & LOCATION: FT RILEY REGION NOS. 7 CENSUS: 2
PROJECT NO. & TITLE: 1 OCCUPANCY SENSORS
FISCAL YEAR 93 DISCRETE PORTION NAME: **INDIVIDUAL OFFICE**
ANALYSIS DATE: 03-24-93 ECONOMIC LIFE 15 YEARS PREPARED BY: TAMULAITIS

1. INVESTMENT

A. CONSTRUCTION COST	$	**110.**
B. SIOH	$	0.
C. DESIGN COST	$	0.
D. SALVAGE VALUE COST	-$	0.
E. TOTAL INVESTMENT (1A + 1B + 1C - 1D)	$	**110.**

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ 11.43	1.	$ 12.	10.77	128.
B. DIST	$ .00	0.	$ 0.	11.54	0.
C. RESID	$ .00	0.	$ 0.	12.68	0.
D. NAT G	$ .00	0.	$ 0.	12.02	0.
E. COAL	$ .00	0.	$ 0.	11.72	0.
F. TOTAL		1.	$ 12.		$ **128.**

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-)		$	0.
(1) DISCOUNT FACTOR (TABLE A)	10.67		
(2) DISCOUNTED SAVING/COST (3A X 3A1)		$	0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 42.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1E)______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YRS ECONOMIC LIFE)) $ 12.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 128.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1E)= **1.16**
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1E/4 **9.25**

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: TOTAL
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.065
INSTALLATION & LOCATION: FT RILEY REGION NOS. 7 CENSUS: 2
PROJECT NO. & TITLE: 1 OCCUPANCY SENSORS
FISCAL YEAR 93 DISCRETE PORTION NAME: **WALL SWITCH FOR OFFICE**
ANALYSIS DATE: 03-24-93 ECONOMIC LIFE 15 YEARS PREPARED BY: TAMULAITIS

1. INVESTMENT

A. CONSTRUCTION COST	$	**60.**
B. SIOH	$	0.
C. DESIGN COST	$	0.
D. SALVAGE VALUE COST	-$	0.
E. TOTAL INVESTMENT (1A + 1B + 1C - 1D)	$	**60.**

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ 11.43	1.	$ 12.	10.77	128.
B. DIST	$ .00	0.	$ 0.	11.54	0.
C. RESID	$ .00	0.	$ 0.	12.68	0.
D. NAT G	$ .00	0.	$ 0.	12.02	0.
E. COAL	$ .00	0.	$ 0.	11.72	0.
F. TOTAL		1.	$ 12.		$ **128.**

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 10.67
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 42.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1E)______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YRS ECONOMIC LIFE)) $ 12.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 128.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1E)= 2.13
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1E/4 5.05

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: TOTAL
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.065
INSTALLATION & LOCATION: FT RILEY REGION NOS. 7 CENSUS: 2
PROJECT NO. & TITLE: 1 OCCUPANCY SENSORS
FISCAL YEAR 93 DISCRETE PORTION NAME: GROUP OFFICE
ANALYSIS DATE: 03-24-93 ECONOMIC LIFE 15 YEARS PREPARED BY: TAMULAITIS

1. INVESTMENT

A. CONSTRUCTION COST	$	110.
B. SIOH	$	0.
C. DESIGN COST	$	0.
D. SALVAGE VALUE COST	-$	0.
E. TOTAL INVESTMENT (1A + 1B + 1C - 1D)	$	110.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ 11.43	2.	$ 21.	10.77	228.
B. DIST	$ .00	0.	$ 0.	11.54	0.
C. RESID	$ .00	0.	$ 0.	12.68	0.
D. NAT G	$ .00	0.	$ 0.	12.02	0.
E. COAL	$ .00	0.	$ 0.	11.72	0.
F. TOTAL		2.	$ 21.		$ 228.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-)		$	0.
(1) DISCOUNT FACTOR (TABLE A)	10.67		
(2) DISCOUNTED SAVING/COST (3A X 3A1)		$	0.
C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4)		$	0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 75.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1E)______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YRS ECONOMIC LIFE)) $ 21.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 228.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1E)= **2.07**
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1E/4 **5.20**

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: TOTAL
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.065
INSTALLATION & LOCATION: FT RILEY REGION NOS. 7 CENSUS: 2
PROJECT NO. & TITLE: 1 OCCUPANCY SENSORS
FISCAL YEAR 93 DISCRETE PORTION NAME: **REST ROOM**
ANALYSIS DATE: 03-24-93 ECONOMIC LIFE 15 YEARS PREPARED BY: TAMULAITIS

1. INVESTMENT

A. CONSTRUCTION COST	$	**110.**
B. SIOH	$	0.
C. DESIGN COST	$	0.
D. SALVAGE VALUE COST	-$	0.
E. TOTAL INVESTMENT (1A + 1B + 1C - 1D)	$	**110.**

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ 11.43	4.	$ 50.	10.77	534.
B. DIST	$ .00	0.	$ 0.	11.54	0.
C. RESID	$ .00	0.	$ 0.	12.68	0.
D. NAT G	$ .00	0.	$ 0.	12.02	0.
E. COAL	$ .00	0.	$ 0.	11.72	0.
F. TOTAL		4.	$ 50		$ **534.**

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 10.67
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 176.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1E)______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YRS ECONOMIC LIFE)) $ 50.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 534.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1E)= **4.86**
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1E/4 **2.22**

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: TOTAL
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.065
INSTALLATION & LOCATION: FT RILEY REGION NOS. 7 CENSUS: 2
PROJECT NO. & TITLE: 1 OCCUPANCY SENSORS
FISCAL YEAR 93 DISCRETE PORTION NAME: **CONFERENCE ROOM**
ANALYSIS DATE: 03-24-93 ECONOMIC LIFE 15 YEARS PREPARED BY: TAMULAITIS

1. INVESTMENT

A. CONSTRUCTION COST	$	**110.**
B. SIOH	$	0.
C. DESIGN COST	$	0.
D. SALVAGE VALUE COST	-$	0.
E. TOTAL INVESTMENT (1A + 1B + 1C - 1D)	$	**110.**

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ 11.43	4.	$ 44.	10.77	474.
B. DIST	$ .00	0.	$ 0.	11.54	0.
C. RESID	$ .00	0.	$ 0.	12.68	0.
D. NAT G	$ .00	0.	$ 0.	12.02	0.
E. COAL	$ .00	0.	$ 0.	11.72	0.
F. TOTAL		4.	$ 44		$ **474.**

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 10.67
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 156.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1E)_____
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YRS ECONOMIC LIFE)) $ 44.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 474.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1E)= 4.31
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1E/4 2.50

APPENDIX B: Manufacturers and Marketers of Occupancy Sensor Lighting Control Products

Manufacturer Name	Made in U.S.	GSA Schedule	Ceiling	Wall
Advance Control Technologies	no	no	XX	I
Bryant Electric	yes	no	I	I
Earlwood Technologies	yes	yes	U	U
Heath Company	no	no	I	I
Honeywell	NA	NA	I	XX
Hubbell (wall)	no	no	I	I
Hubbell (ceiling)	yes	no	I	I
Leviton	NA	NA	I	I
Lightolier	yes	no	I	I
Lithonia	yes	no	U	U
MyTech	yes	yes	U	I, U
Novitas (wall)	no	no	U	I, U
Novitas (ceiling)	yes	no	U	I
Pace Technologies	no	no	XX	I
Sensor Switch	NA	NA	I	I
Tork	yes	no	I	I
Unenco	yes	yes	I, U	I
Watt Stopper	yes	yes	I, U	I

<u>Key</u>:
NA: information not available at time of writing
XX: not manufactured
I: infrared sensor
U: ultrasonic sensor

ABBREVIATIONS AND ACRONYMS

CEGS	Corps of Engineers Guide Specifications
USACPW	U.S. Army Center for Public Works
DEH OMA	Directorate of Engineering and Housing, Operation and Maintenance, Army
ECIP	Energy Conservation Investment Program
FEAP	Facilities Engineering Applications Program
GSA	General Services Administration
IR	infrared
LCC	life cycle cost
LCCID	Life Cycle Cost in Design Program
LED	light emitting diode
MACOM	Major Army Command
M&R	maintenance and repair
SPST	single pole, single throw switch

☆ U.S. GOVERNMENT PRINTING OFFICE: 1994—3510-S/00036